



Technical Document TRAC-TD-0393
October 1993

COMMAND AND CONTROL MEASURES OF EFFECTIVENESS HANDBOOK

TRADOC Analysis Center
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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE OCT 1993		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Command and Control Measures of Effectiveness Handbook				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) TRADOC Analysis Center Study and Analysis Center Fort Leavenworth, KS 66027-2345				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 46	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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COMMAND AND CONTROL
MEASURES OF EFFECTIVENESS
HANDBOOK
(C2MOE HANDBOOK)

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ACKNOWLEDGMENTS

The Command and Control Measures of Effectiveness (C2MOE) Handbook development was directed by Mr. Donald W. Kroening, Director, Studies Directorate, TRADOC Analysis Center-Studies and Analysis Center (TRAC-SAC). This technical document reflects the TRAC approach to the problem of developing consistent and meaningful C2MOE. The author attempted to integrate the positions and contributions provided by many individuals and organizations throughout the Fort Leavenworth and Army communities. Listed below are the organizations, and or individuals who provided some input directly or indirectly to the development of this document.

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Abstract

This technical document presents a methodology for the development and use of command and control measures of effectiveness (C2MOE) that can be used by the training, test and evaluation, analysis, and research communities to perform their associated missions.

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CHAPTER 1

INTRODUCTION

1-1. Purpose. The purpose of this handbook is to present a methodology for the development and use of command and control measures of effectiveness (C2MOE) that can be used by the training, test and evaluation, analysis, and research communities to perform their associated missions.

1-2. Scope. This handbook specifically deals with the process for developing measures of effectiveness for command and control (C2) systems. The word “system” as used hereafter should be considered as encompassing doctrinal, training, leader development, organizational or materiel alternatives and combinations of these as appropriate. This process is applicable to all types of training, test and evaluation, analysis, and research efforts concerning C2 systems. This process is intended to provide some uniformity of effort in the analytical community in developing C2MOE and help in establishing a common ground of reference for work within the community. This effort is not all encompassing but provides a reasonable and coordinated methodology. This handbook also provides a listing of C2MOE that have been used in the past with an explanation of what the measure of effectiveness (MOE) is, how it is used, its limitations, and other pertinent information.

1-3. Objective of the Handbook. The objective of this handbook is to assist analysts charged with the examination of C2 systems. This handbook is intended to be a timely reference that will help in developing MOE for C2 that are understood and common to the whole analytical community. There are common threads that bind the three analytical communities of training, test and evaluation, and research and analysis together. Table 1-1 below demonstrates these common threads. In table 1-1, the three columns represent the three general areas of the analytical community while the rows represent the common parameters with which each of the groups deals or identifies. They are in essence the same throughout. The key to developing MOE is that if they do not address a decisionmaker’s issues or concerns, they are of no use.

Table 1-1. The common threads of analysis.

Training	Test and Evaluation	Analysis
Task	Issue	Issue/EEA
Conditions	Scope	Scenario
Standards	Criteria	MOE/MOP

1-4. Use of the handbook. This handbook is recommended for use by all analysts or other action officer personnel in developing MOE for studies, evaluations, tests or other analytical examinations of C2 doctrine, training, leadership, organizational, and materiel issues. This handbook is not intended to be all inclusive but to serve as a guide.

1-5. Revisions. It is envisioned that new C2MOE will be developed from time to time and there will be a desire to provide input to update this handbook. Developers of new C2MOE are encouraged to provide input to update this handbook by forwarding them to Director, TRAC Studies Directorate, Study and Analysis Center, ATTN: ATRC-SAS, Fort Leavenworth, KS 66027-2345.

1-6. A friendly reminder. The one thing most often forgotten and ignored by analysts, testers and evaluators, and trainers is that they are not the ones making the decisions. They are collecting data and information, performing an analysis of that information, and making recommendations based upon the analysis. Under all circumstances, the decision maker is free to make whatever decision he chooses, and that decision may be driven by elements or conditions outside the realm of the analysis and recommendations provided.

1-7. References.

- a. *Force Developments, The Measures of Effectiveness.* USACDC Pamphlet 71-1, Fort Belvoir, VA, January 1973.
- b. *Test Measures Catalog* (supplement to USACDC Pamphlet 71-1). Operations Research Institute (ORI) Inc., Rockville, MD, September 1987.
- c. *Command and Control Measures: A Proposed Approach.* Mr. Michael Ingram and CPT Robert Short, C3I Studies and Analysis Directorate, TRAC-OAC, Fort Leavenworth, KS, July 1991.
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- e. Review of Research and Methodologies Relevant to Army Command and Control Performance Measurement. U.S. Army Research Institute for the Behavioral and Social Sciences, January 1989.
- f. *Timeliness and Measures of Effectiveness in Command and Control.* Philippe H. Cothier and Alexander H. Levis, IEEE, November/December 1986.
- g. Handbook for Operational Issues and Criteria - Second Edition. Operational Test and Evaluation Agency, August 1989.
- h. Handbook for the Independent Operational Evaluation of Concept-Based Requirement System (CBRS) Products. TRADOC Pamphlet 71-13 (Draft), 1990.
- i. *Troop Test Methodology Guide.* Technical Operations, Inc., Combat Operations Group, Alexandria, VA., October 1967.

CHAPTER 2

INSTRUCTIONS

2-1. Problem statement. A requirement for a standardized set of C2MOE for all analytical communities (training, test and evaluation, analysis and research) to perform their associated missions and a methodology for the development of this set, has been recognized by members of the Military Operations Research Society (MORS) as a major problem facing the Army. C2MOE are required to measure and evaluate the operation and performance of C2 systems in a combat context. The lack of a standardized set of C2MOE has resulted in the development of measures on a study-by-study basis. Most previous C2MOE have not clearly linked changes in C2 systems or doctrine to battle outcome. C2MOE have tended to be anecdotal in nature. They have depended upon a high degree of human interaction, and thus, have been prone to inconsistency in either measure or application. In addition, because C2MOE are difficult to identify, in most studies and evaluations very few are used. Evaluating a C2 system with just one or two MOE can limit the focus of a study and place the resulting conclusions in jeopardy.

2-2. C2 definitions.

- a. Command and control is defined by Joint Chiefs of Staff Publication 1 (JCS Pub 1) as:

The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of this mission.

- b. Also from the draft FM 71-100-1, Heavy Division Tactics and Techniques, Chapter 3, Heavy Division Command and Control, the following definition directly applies:

Command and control is not one word!

Command is the art of assigning missions, prioritizing resources, guiding and directing subordinates, and focusing the entire division's energy to accomplish clear objectives.

Control is the science of defining limits, computing requirements, allocating resources, prescribing requirements for reports, monitoring performance, identifying and correcting deviations from guidance, and directing subordinate actions to accomplish the commander's intent.

- c. From these definitions, we can develop the premise that C2 has six components: physical entities, structure, tasks or activities, process, function, and doctrinal objective or mission (see figure 2-1). As shown in figure 2-1, the lower components are derived from the higher components, reflecting the Army policy that doctrine drives our development of training,

organizational structures, leaders, and materiel equipment. We evaluate or judge our degree of success in accomplishing the top objective or mission by starting at the bottom and working our way up the ladder, assessing how well we are as we go, and trying to determine if and how much of an impact what was done below effects the next higher levels.

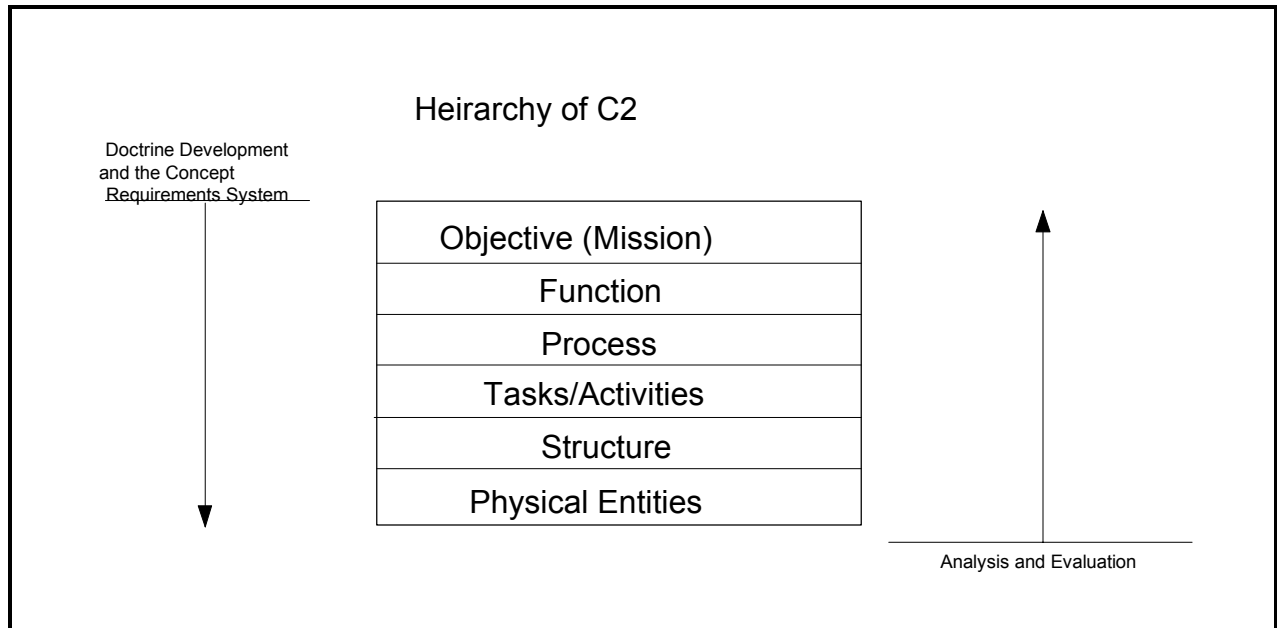


Figure 2-1. Hierarchy of C2 components.

- (1) Physical entities refer to equipment, software, facilities, and people. These are arranged into structures.
- (2) Structure identifies the arrangement and interrelationships of physical entities, procedures, protocols, concepts of operation, and information patterns. Such arrangements are often spatial and temporal. These structures are created to perform tasks or activities.
- (3) Tasks or activities refer to individual and collective work or actions taken by the entities and the structure, as a whole, as a part of a process.
- (4) Process is a reference to the arrangement and interrelationships of tasks or activities that are performed to fulfill functions defined by doctrine.
- (5) Function is an aggregated listing of tasks, activities, and/or processes that describe what and how the Army will go about achieving its doctrinally defined objectives or missions.
- (6) Objectives or missions are the descriptive terms used to identify desired end states or achievements as a result of employing Army forces.

2-3. What is an MOE?

a. Types of measures. There are numerous types of measures that have been used to evaluate C2 systems in the past. The following definitions will help in understanding what makes up MOE.

(1) Dimensional parameter. A property or characteristic inherent in the physical entities whose value (e.g., size, weight, capacity, number of pixels) determines system behavior and the structure under question even when at rest .

(2) Command and control measures of performance (C2MOP). Related to the inherent parameters (physical, structural, task/activity, and process) but represents a measurement of an attribute of system behavior (e.g., throughput, error rate, process resource requirements (time, space, quantities of physical entities)). C2MOP are internal to the system being analyzed and are scenario-independent. These may be derived from measures of effectiveness or directly from an issues/EEA.

(3) Command and control measurements of effectiveness (C2MOE). A measure of how a C2 system affects the other entities within an operational environment (e.g., reaction time, susceptibility to deception). C2MOE are measured relative to some perceived standard, which is often implicit (e.g., how a perfect C2 *system* would perform). C2MOE are scenario-dependent. These may be derived from measures of force effectiveness or directly from issues/EEA.

(4) Measures of force effectiveness (MOFE). A measure of how the force performs its mission. As with C2MOE, MOFE are scenario-dependent. These are derived directly from issues/EEA.

(5) Boundary of a C2 system. The delineation between the C2 *system* being studied and the environment. Within this definition, measures can shift from one type to another depending on the context of the C2 system boundary. Figure 2-2 graphically shows the relationship of the measures defined above.

(6) Objective measures are those that are based on facts and tend to be unbiased. They are in large part captured through physical observation or recording of some physical change observed about physical entities (e.g., time, size, shape, physical condition, quantity).

(7) Subjective measures are those that place emphasis or reliance on one's own moods, attitudes or opinions, experiences and values. They may be biased in many ways and forms. They reflect the perceptions of the observer of multivariate inputs. As both C2MOE and MOFE are both scenario dependent, they are by their very nature more in the subjective realm than the objective. The definitions of "win, lose, or draw" are dependent on the scenario and the perception of the participants.

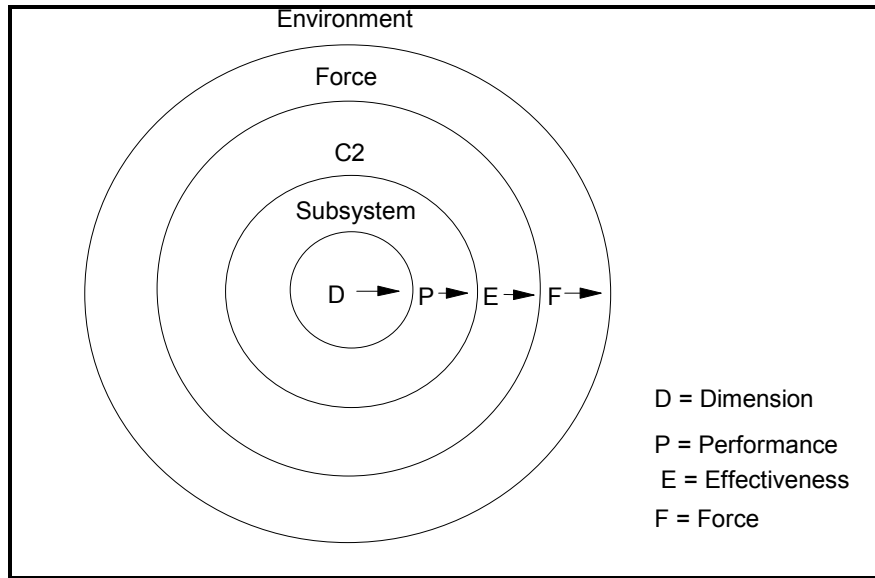


Figure 2-2. Measure relationships.

b. Desired criteria and characteristics for C2MOE. One of the most desirable goals in developing C2MOE is to ensure that the characteristics are measurable and quantitative. Analysis is strengthened and gains credibility when conducted with objective measurements as opposed to subjective measurements. A 1985 Military Operations Research Society workshop developed a table of desired characteristics for measures. The characteristics that C2MOE should possess were also defined. The purpose of these characteristics was to ensure that C2MOE were described by measurable and objective attributes as opposed to subjective evaluation. These desirable characteristics are listed below in table 2-1.

Table 2-1. C2MOE desired characteristics

Characteristic	Definition
Mission-oriented	Related to force/system mission
Discriminatory	Identify real differences between alternatives
Measurable	Able to be observed, recorded or estimated
Quantitative	Able to be assigned numbers or rank
Realistic	Relate realistically to the C2 system and associated uncertainties
Objective	Defined or derived; independent of subjective opinion (it is recognized that some measures cannot be objectively defined)
Appropriate	Relate to acceptable standards and analysis objectives
Sensitive	Reflect changes in system variables
Inclusive	Reflect those standards required by the analysis objectives
Independent*	Mutually exclusive with respect to all other measures
Simple	Easily understood

*Desired but not essential

2-4. Understanding the problem. The first step toward trying to solve the problem of standardized (or at least mutually agreed to) C2MOE is developing a common understanding of

the problems involved in developing meaningful MOE. Figure 2-3 graphically shows the problem—the higher we go up the ladder in the hierarchy of the components, the more we shift from objective measurable things to subjective measurable things.

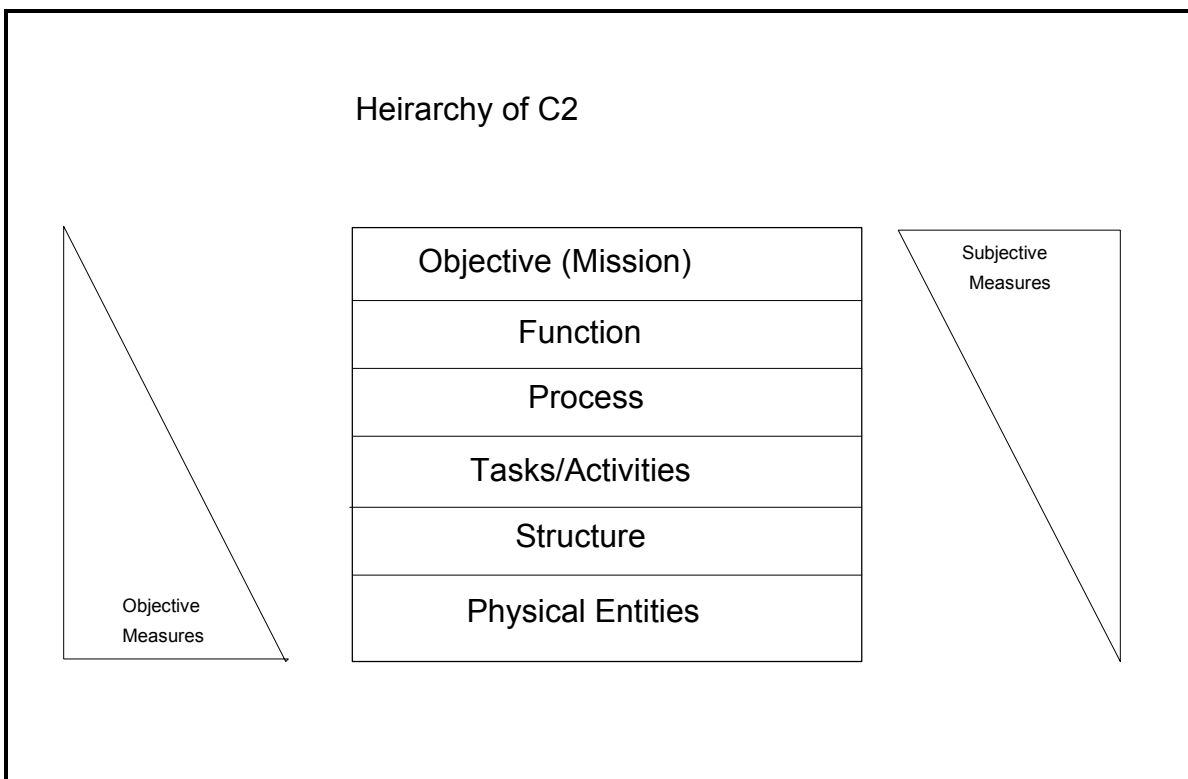


Figure 2-3. Relationship of objective to subjective measures on the hierarchy.

- a. *Why objective measures at the bottom.* Here we are dealing with more physical entities, how they are arranged and organized, what they are doing or are being used for. These things tend to be measurable and observable more in the physical sense. Since there are more of these physical entities, activities, and processes at the lower end of the hierarchy, there are more objective measures at that end of the scale.
- b. *Why subjective measures at the top.* Here we are dealing with conceptual and perceptual ideas concerning a desired end state or goal/objective. These are the mental pictures, if you will, of how we see things existing. They are not physical entities and, therefore, tend to lack substance that can be measured. As many humans develop similar but not identical perceptions of a desired end state or goal (e.g., win, lose, or draw), it is not practical or in most cases possible to objectively quantify those end states. Also, there are a multitude of variable inputs that go into those mental perceptions from basic instincts to physical health and emotional stability. These multivariate inputs make it much easier and more desirable to evaluate the end states in a subjective form.
- c. *The understanding.* The above two paragraphs lay out the underlying problem that most analysts have when they try to objectively quantify and evaluate subjective conceptual and

perceptual things. In most cases it does not work well and there is great confusion. Also, we have to understand that although there are many variables that can effect the desired end state, one or many of those variables may change (some drastically) yet no noticeable or perceived change will occur in the end state. Examples of this include:

- (1) Changing physical entities without a resulting change in end state.
- (2) Changing structure without changing end state.
- (3) Changing tasks or activities without changing end state.
- (4) Changing processes without changing the end state.

When things change and there is no noticeable or perceived change in the end state, it is futile to try to base decisions on the effect. Other criteria or measures must then be used for supporting the change. The primary measure that exists is change in resource requirements. This may be less equipment, personnel, fuel, time, space, or money. Any and all of these may provide valid and substantial reasoning for making a proposed change. We have to recognize this and relay it to the decisionmakers up front. They are the ones that must be satisfied with the answers we provide to their questions. This means that many times we will have to sell our analysis and the rationale for what and how we are doing things to the decisionmaker before we start.

2-5. How to develop MOE. The best methodology for developing MOE is the structured resolution/functional decomposition approach. This methodology will allow the analyst to go from the decisionmakers questions/issues/concerns down to the data-element level of detail.

a. *How does it work?* The process starts with the decisionmaker's issue or question.

(1) The tie that binds. As mentioned before, there must be a tie or link between the C2 system, the decisionmakers questions and the hierarchy of C2 components. Table 2-2 is representative of how these ties can and should be made.

Table 2-2. Links to the C2 system hierarchy.

Component	What comprises the component
Objective	Doctrine (AirLand Battle tenets and imperatives)
Function	Functions as described in the "Blueprint of the Battlefield"
Process	The interconnectivity required among the tasks/activities for the functions to be satisfied.
Task/Activity	The individual and collective tasks/activities as described in soldiers manuals and ARTEPs and METLs.
Structure	The TOE/MTOE and other force design documents.
Physical Entity	Materiel equipment items and personnel. (<u>The</u> resources.)

(2) Make a rough outline of the links. Once all the links and ties to the hierarchy have been made, they should be laid down in a rough outline to help develop a picture of the interrelationships and implications of the problem or question. This outline will be used to develop the detailed questions/issues and measures required to answer the decisionmaker's question.

(3) Simplify the question. Most of the time, the questions the decisionmakers have are very broad, one-over-the-world type questions that are not in a suitable form for evaluation. The problem for the analyst is to break those high-level questions down through a systematic functional decomposition that results in the development of issues or questions that are specifically worded to obtain data. That functional decomposition is or should be based on the components and characteristics of the higher level issues (see figure 2-4.)

(a) Issues are questions that are designed to provide the decisionmaker with the information required to reduce the risk in making a decision. The issues provide a guide to the systematic investigation of the question(s) (and implied problem(s)). This systematic investigation or inquiry is based on a problem solving procedure that is organized to seek an answer to a clearly stated question. The way the analyst defines a problem and formulates questions may determine the difference between a poorly conducted analysis or evaluation and a successful one. The following example illustrates the contribution that problem definition can make to the solution process.

An automobile traveling on a deserted road blows a tire. The occupants discover that there is no jack in the trunk. They define the problem as finding a jack and decide to walk to a service station for a jack. Another automobile on a similar road also blows a tire. The occupants also discover there is no jack. They define the problem as raising the automobile. They see an old barn with a pulley for lifting bails of hay to the loft. Recognizing a potential raiser, they push the car to the barn, hoist it with the pulley, change the tire, and drive off while the occupants of the first car are still trudging toward the service station.

As can be seen from the above example, issues are developed from conceptual and perceptual requirements. They guide the conduct of the evaluation or analysis. The issues are a series of questions that form the basis for a plan for obtaining answers. As information concerning the questions is obtained, it is synthesized within a logical framework to provide an estimate. The estimate is based upon the best information available and used to reduce the amount of risk in the decisionmaking process. Issues provide a focus to gather factual information needed to develop logical conclusions and recommendations.

(b) The relationships among decisionmaker questions, issues, and data requirements are shown in figure 2-4. Through the functional decomposition of the decision makers questions; issues, subissues, essential elements of analysis (EEA), MOFE, MOE, MOP (criteria or standards) and data requirements are developed which guide and direct the analytical work that must be done. Issues provide a logical bridge between the decisionmaker's questions and the data requirements. They also provide a logical bridge during the synthesis of the data collected to answer the questions. Once the data has been collected and analyzed, the synthesis process takes the results of the analytical work and builds up through the hierarchy (the reverse of the functional decomposition process) to arrive at answers to the decisionmaker's question.

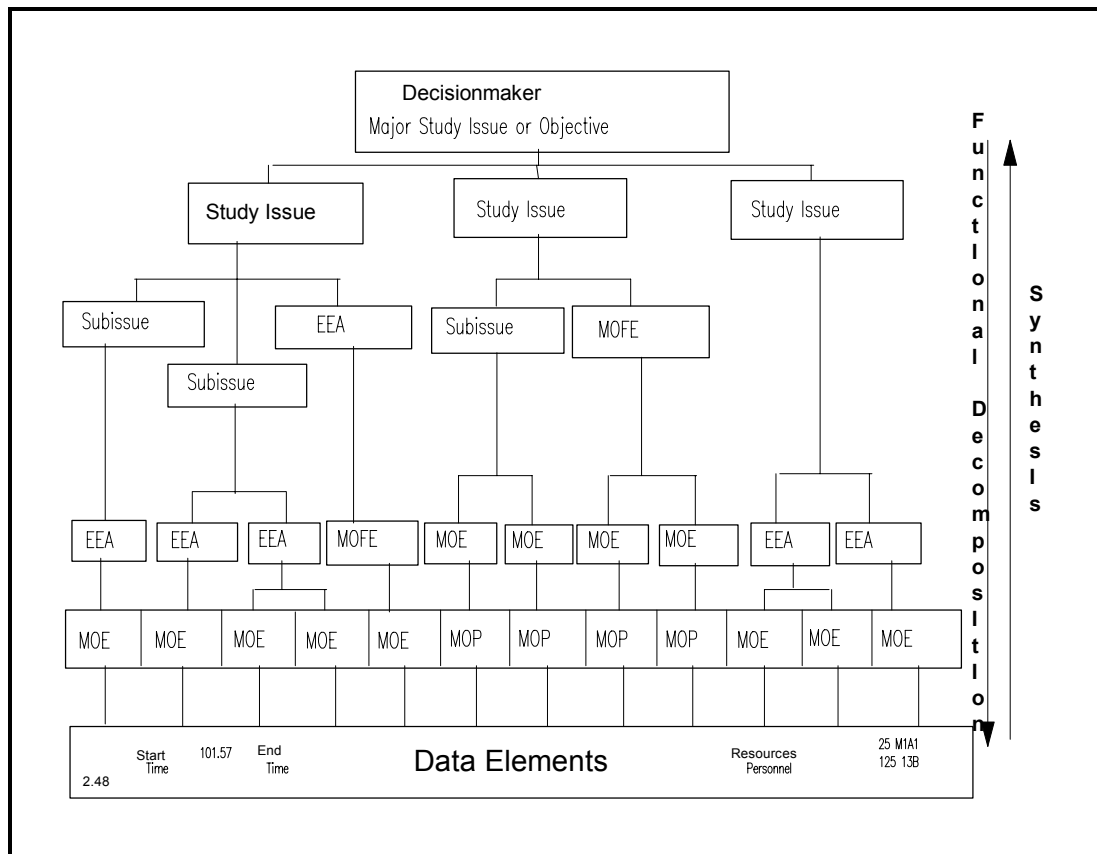


Figure 2-4. Question, issue, data relationships

b. *How to simplify the question.* As shown in figure 2-5 below, this is an iterative process of linking the C2 system and decisionmakers questions to the C2 hierarchical components (from the rough outline) and asking the question, “Can this question be answered directly?” If the question can be answered directly, then see if the answer can be quantified. If the answer cannot be quantified, then you examine the use of a subjective evaluation. If the question cannot be answered subjectively or that is unacceptable, examine the use of some resource type analysis (cost benefit), or try to get the decisionmaker to change the question or at least understand the limits of the answer that can be provided. If that is still unacceptable, then look at further decomposition of the question (e.g., go lower in the hierarchy).

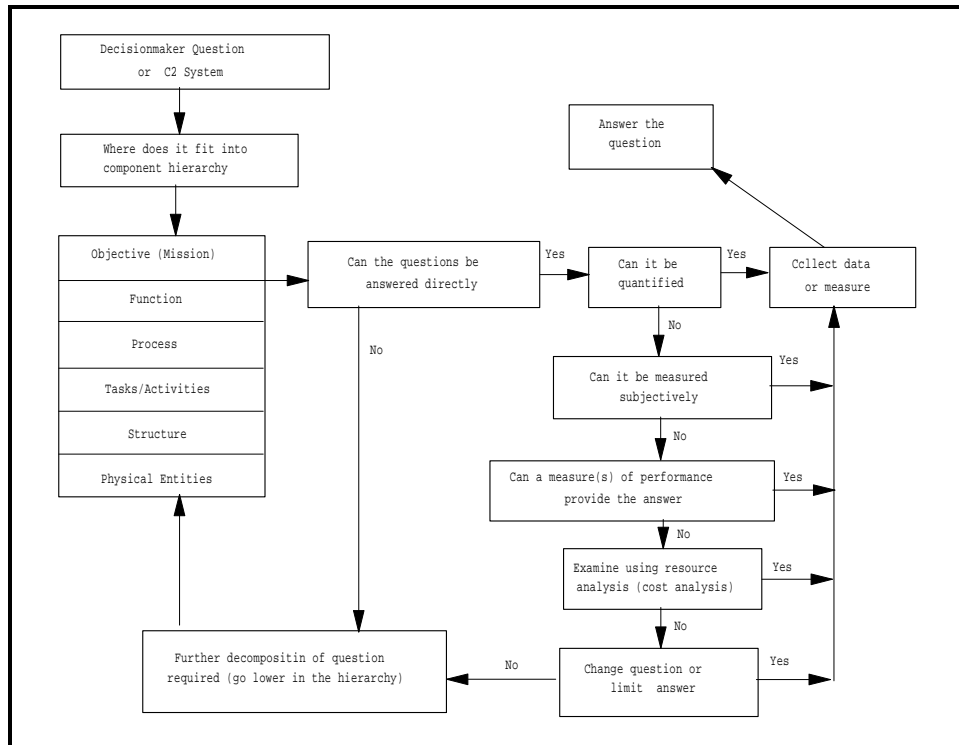


Figure 2-5. Iterative issue decomposition

C. *Build a logic tree.* A logic tree is a graphical representation (a dendritic network) used to portray the interconnectivity of a logical network used in decomposing the decisionmakers questions into issues. This is very similar to the logic and flow networks used in CPM and program review and evaluation technique (PERT) diagrams. It is derived from the rough outline using the process described above.

(1) A logic tree is used to ensure consistency of reasoning in the detailed refinement of the issues. Each issue is refined into successively simpler information requirements and eventually arrives at the data requirements. This subdivision process continues through as many levels as required to establish data requirements.

(2) As indicated in figure 2-4, the completed logic tree provides a framework for the analyst to verify that all data requirements necessary to satisfy the decisionmaker's information requirements have been documented. As also shown in figure 2-4, the analyst can verify the data requirements by starting at the bottom of the logic tree and working his way back through the network (the synthesis process) to ensure that the data requirements answer the parent question. This same procedure is repeated throughout all levels of the network until the analyst reaches the decisionmaker's question and is satisfied that all the data required to answer the question has been included.

d. *A stumbling block.* If you haven't guessed by now, there is one trick to this process. Generally, the C2 system we are evaluating and the decisionmakers questions don't fall on the same level of the hierarchy of components. For example, we are dealing with a structural issue

and the decisionmaker wants to know the impact on the outcome of the battle (from the objective standpoint). There may be a tendency to force the analysis to show some change in battle outcome and attribute that to the change in structure. That may or may not be true and such analyses may present false pictures. A thorough analysis should examine the system as it impacts the whole hierarchy. It is possible to have changes at any level of the hierarchy cause a ripple of changes in other levels of the hierarchy without significantly changing the overall outcome but, at the same time, producing great efficiencies in resource cost and utilization. For example: a C2 system for logistics units could very realistically not change how well we win the battle in terms of increased tank kills but still make an indirect impact of contribution through more efficient resource utilization.

2-6. Example. The best way to explain how to use the process is through example. The following is an example of how this process may work. There is no one solution and this example will not/can not address all possible aspects of the question. For our example we will assume that we have been charged to evaluate the adequacy of a set of procedures for the synchronization of the air and ground campaigns in a theater of operations.

a. *Step 1- starting at the top.* Our first step is to look at the question or problem and link it to the C2 hierarchy and rough out an outline of the places and ways the link(s) occur. Figure 2-6 is an example of our outline. It is a stubby pencil brainstorming session that we have scratched out on paper.

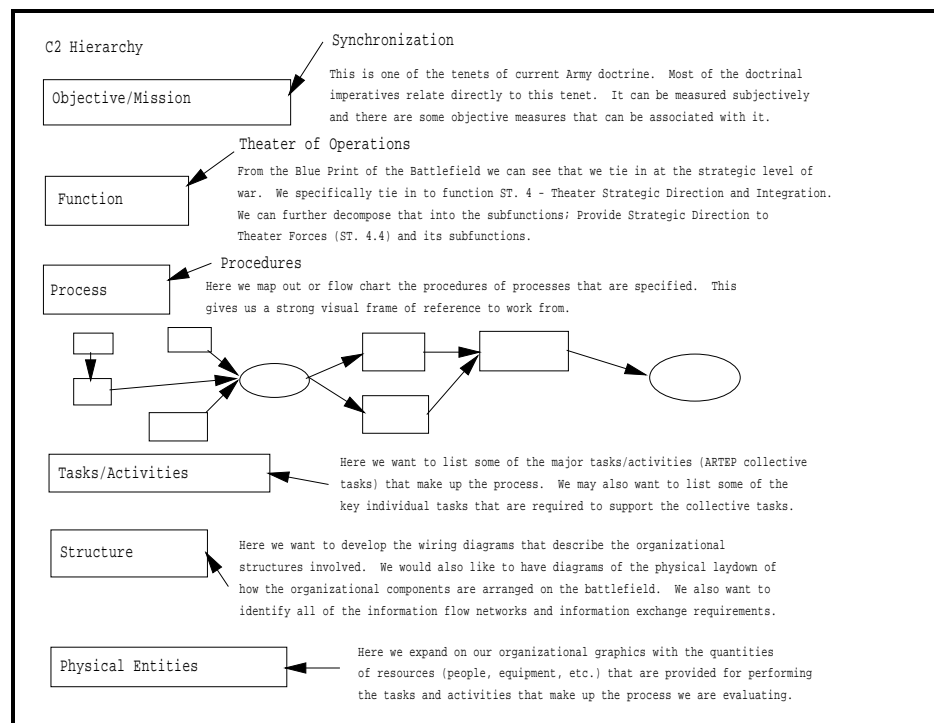


Figure 2-6. Hierarchical link and outline process

b. *Step 2.* Now we work through our outline that we have developed and write associated questions/issues. For example: Our top issue might be—What effect do the new procedures

have on the synchronization of the air and ground campaigns in the theater of operations? We may begin by asking what makes up synchronization? Synchronization is the arranging of activities in time and space to mass at a decisive point, it involves resource allocation and utilization, it is subjective. It can be indirectly measured through the correlation of separate discrete events to a timeline of activities that come together to generate a desired outcome. An example of measures and data that could be used to examine the relative value of synchronization are:

Measures - Relation of key events over time

Sequence of key events

Data - Event occurrence

Event start time

Event end time

Total time line of events

Subordinate issues from the area of battlefield functions may be:

- How well do the procedures support the provision of strategic direction to theater forces?
- What effects do the procedures have on the preparation and coordination of theater strategy, campaign plans, operations plans and orders?
- What effects do the procedures have on the issuing of strategic and contingency plans and orders?
- What effects do the procedures have on the theater command's ability to orchestrate unified operations and subordinate campaign plans?

These questions will then beget issues about the procedures (process) itself. For example: Do the procedures provide for the integration and coordination of target nominations? (i.e., Does it provide for the identification and elimination of duplications?). This is where we get into the iterative process of working through the functional decomposition of the issues (figure 2-5). Now our number of potential questions will begin to expand rapidly. There are many objective measurable things that can be associated with processes, tasks/activities, structures and physical entities. Some of these, in general are:

(1) Process. Do the new procedures improve the timeliness of ground and air response to changes in campaign priorities?

Measure - elapsed time or time in process

Data - Start time = time change identified

End time = issue of change order by theater headquarters

- Do the new procedures improve the responsiveness of the staff in issuing plans?

Measure - time required to issue a plan

Data - Start time = start time of planning process - identification of need
by commander

End time = when plan is issued/sent to subordinate units

•Do the new procedures improve the responsiveness of the staff in issuing orders and fragmentary orders (FRAGOs)?

Measure - order/FRAGO preparation time (based on a change from existing plan)

Data - Start time = time need for change identified

End time = time order issued

(2) Task/activities. Are any new collective/individual tasks required to be performed?

Measure - change in the number of tasks required - old versus new procedures

Data - Number of tasks for old procedures

Number of tasks for new procedures

•What is the change in the staff workload requirements for the new tasks?

Measure - change in staff workload - change in percent of time staff is occupied versus percent of time staff idle

Data - Time occupied by old tasks

Time idle under old procedures

Time occupied by new tasks

Time idle under new procedures

•How much time and resources are required for training the staff in the new tasks and procedures?

Measures - Change in training time required

Change in training facilities required

Changes in training personnel required

Changes in training costs

Changes in training retention

Changes in frequency of refresher training required

Data - Training time required old procedures

Training time required new procedures

Training facilities required old procedures

Training facilities required new procedures

Personnel required to train old procedures

Personnel required to train new procedures

Average time from initial training until refresher training required - old procedures

Average time from initial training until refresher training required - new procedures

Average time between refresher training sessions acceptable to maintain 80 percent efficiency at task accomplishment old procedures

Average time between refresher training sessions acceptable to maintain 80 percent efficiency at task accomplishment new procedures

- Does the training provided permit the effective and efficient performance of the tasks?
- Are any new skills and knowledges required for the individuals performing the required tasks?

(3) Structure. What are the resource impacts of implementing the new procedures?

- Do the procedures require an increase in resources (personnel and equipment) above current levels?

Measures - Changes in personnel and equipment

Data - Personnel required for old procedures

Personnel required for new procedures

Equipment required for old procedures

Equipment required for new procedures

- Are there (will there be) enough resources available to accomplish the tasks required in a timely manner?

Measures - Change in resources required to accomplish the tasks old versus new

Data - Resources required (personnel and equipment) old procedures

Resources required (personnel and equipment) new procedures

Time required old procedures

Time required new procedures

- How do the information exchange requirements differ between the new and current processes?

Measures - Changes in information to be exchanged

Changes in resources required for information exchange

Data - Data elements required for exchange old procedures

Data elements required for exchange new procedures

Resources required for old procedures

Resources required for new procedures

- How much redundancy is there in the information exchange requirements?

Measures - Number of data elements repeated each exchange

Number of sources for the same data
Frequency of repetition of the same data
Data - Data elements for each exchange
List of sources for each data element
Number of incidence's of repetition of the same data

(4) Physical entities. What impacts are there on the Army personnel system from the changes in personnel requirements?

•How many more XXXX soldiers will have to be recruited and trained to fulfill the new Army requirements?

Measure - Change in requirements for XXXX soldiers
Data - Number of accessions required old
Number of accessions required new
Number of personnel required to be trained old
Number of personnel required to be trained new

•How many system Ys are required to support the new procedures?

Measure - Change in number of system Y required
Data - Number of system Y required old
Number of system Y required new

•Is the Y system maintainable within the current Army logistic support structure.

hour) Measures - Maintenance Ratio (maintenance manhours/operating

Data - Total system operating hours
Total maintenance manhours expended

•Does system Y posses the capability to handle the necessary information exchange requirements?

Measures - Demonstrated to desired capability ratio
Data - Desired capability
Demonstrated capability

c. *Step 3.* Build a dendritic of the work that has been done so far and make sure it goes down to the data-element level of detail. If it does not, continue to expand it until you get to this level. As you become proficient at the process, it will become more convenient and easy to combine steps 2 and 3 into one process. That will result in using the dendritic construction process to do the functional decomposition of the issues.

d. *Step 4.* Work backward through the dendritic network to ensure that the data collected answers all the subordinate questions all the way up to the key decisionmakers question. Try to

eliminate those things that do not fit or are redundant. Clearly identify those areas where the data or information required is not obtainable and the reason it cannot be obtained. These limitations must be identified in the study report. They provide the decision maker with extra information for his risk assessment in making his decision.

2-7. A word about data. Although data is not a specific topic of the handbook, some mention must be made of the limitations data can impose on the development of truly meaningful and usable MOE. It does no good to develop MOE for which data can not be collected, for either physical or time constraints or economic reasons. Therefore, this process must be tempered with the realities of our ability to obtain the necessary data to satisfy the MOE and answer the questions. If we can not reasonably obtain the data, then the MOE is of little or no value to the decision process and should be deleted. If necessary, other MOE, EEA, or issues should be developed to try to address the decisionmaker's concerns. Also, the decisionmaker must be made aware of the limitations posed by the nonavailability of data and/or the resource requirements to develop the data.

2-8. Summary. As command and control is a combination of both art and science, so is the analysis or evaluation of it. The methodology for formulating the analysis is scientific, but the application of it to get meaningful answers is truly an art. As commanders learn through experience the intricacies of exercising their command authority, so do analysts learn the intricacies of how to apply their scientific methods to satisfy the decisionmaker's concerns. The simpler and more relational the answer is to the real world, the more likely it is that others will understand it. The best analytical work in the world is useless if the person who needs the output cannot understand it and relate it to the real world.

CHAPTER 3

C2MOE CATALOG

3-1. General. This chapter lists some C2MOE that have been used in previously completed studies, tests, evaluations, and/or research. This catalog is by no means complete. Significant additional effort is required to update this catalog with C2MOE from recent and on-going C2 analyses, tests, evaluations, and research efforts.

3-2. C2MOE definition format. The following criteria are used to define and explain the C2MOE listed in this handbook. This format should be used for all MOE submitted for inclusion into this handbook.

a. *Definition of the measure.* A complete statement of the measure which includes computational data and methods of processing.

b. *Dimension of the measure.* How the measure is expressed (level and unit of measure). Levels of measure include nominal, ordinal, interval, and ratio. Examples of units of measure include: integer, real; green, amber, red; high, medium, low; and kilometers per hour, 80 percent.

c. *Limits on the range of measure.* Statement of any limits on input or output of the measure.

d. *Rationale for the measure.* Why the measure was selected and what properties make it useful.

e. *Relevance of the measure.* Circumstances (analyses, studies, etc.) in which the measure would contribute to the decision process.

f. *Associated measures.* Other measures which either may be used in conjunction with the measures or which must be used with it to appropriately evaluate the C2 issue.

g. *Applications.* Studies, tests, or evaluations in which the measure was used or observed.

h. *References.* Sources that provide any additional discussion of the measure and its use.

3-3. C2MOE listing.

<u>C2MOE</u>	<u>Page</u>
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<u>C2MOE</u>	<u>Page</u>
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3-4. C2MOE Catalog.

MOE #1: SYSTEM CONTRIBUTION TO THE COMMANDER'S PERCEPTION OF THE ENEMY

1. Definition of the measure. This is a comparative measure of a systems contribution to the commander's perception of the current battlefield situation has a direct impact on the decisions made by the commander. This MOE is not addressable directly, but is through subordinate measures of performance (MOP). The primary one used in the application listed below is the amount and age of intelligence over time. This is the total number of units upon which there is intelligence information in a database and the age of that intelligence information. The output is a cumulative graph of number of units upon which there is intelligence information versus time.

2. Dimension of the measure. Interval -- the number of units upon which intelligence information is available, the current time within the scenario, and the age (in time (i.e., seconds, minutes, hours) of the intelligence information.

3. Limits of the range of the measure. There is no apparent limit on the output values; they can assume the value of zero or any positive integer.

4. Rationale for the measure. This measure can address the contribution of a system to the commander's decision-making process and provide for a comparative analysis of alternatives for supporting the commander's decision-making process.

5. Relevance of the measure. This measure may be used to compare changes in C2 effectiveness based upon support from C2 related systems such as intelligence systems (i.e., ASAS). It provides for a comparison of the effectiveness of C2 decisions when the basis for the decision-making (the intelligence information available) changes because of changes in the subordinate systems supporting the decision-making process.

6. Associated measures.

Required number of commands
Reaction time (time to order)

Changes per order

7. Applications.

Block II All-Source Analysis System Cost and Operational Effectiveness Analysis
(Block II ASAS COEA), TRADOC Analysis Command, Technical Report TRAC-TR-0493,
June 1993.

8. References.

MOE #2: RATIO OF SUPPLIES CONSUMED VERSUS PROVIDED

1. Definition of the measure. Ratio of the quantity of supplies consumed to the quantity of supplies provided by the CSS system. Input data is the quantity of supply (by class) consumed (Q_c) and the quantity of supply (by class) provided (Q_p). The relationship of input to output is:

$$Ratio = \frac{Q_c}{Q_p}$$

2. Dimension of the measure. Ratio -- the output is a pure number expressing a ratio.

3. Limits on the range of the measure. The output value may vary from one to infinity.

4. Rationale for the measure. This measure addresses the relative degree to which supply consumption can be satisfied by the CSS system. It is assumed that with faster CSSC2 system will speed and enhance the satisfaction of supply demands therefore reducing the ratio towards one.

5. Relevance of the measure. The measure is used as a comparison across alternatives rather than against the perfect ratio.

6. Associated measures.

7. Applications.

US/UK Command and Control Study, March 1993.

8. References. None.

MOE # 3: PROPORTION FIRE REQUESTS BEYOND RANGE

1. Definition of the measure. Proportion fire requests beyond range is the proportion of all fire missions requested (or required in the case of a simulation) that are not fired because the target is beyond range. Input data are the total number of fire missions required and number denied because target is beyond range. Relation of output to input is:

$$\frac{\text{proportion fire requests beyond range}}{\text{requests beyond range}} = \frac{(\text{number of requests}) - (\text{number denied for range})}{\text{number of requests}}$$

2. Dimension of the measure. Ratio -- output is a fraction expressing proportion.

3. Limits on the range of the measure. Output can vary from zero to unity.

4. Rational for the measure. This measure is a direct assessment of the effectiveness of a firepower system in meeting requirements, taking range into account.

5. Relevance of the measure. The measure can be used to evaluate a firepower system. Indirectly, it may be used to evaluate a C2 system because the largest single factor in the measure may be deployment of fire support assets in relation to the supported force mission.

6. Associated measures.

Percent fire request met
Area coverage

Maximum effective range

7. Application.

Reserve Components Revised ATT, USCONARC, March 1972.

8. References.

MOE # 4: NUMBER OF OPTIONS REMAINING

1. Definition of the measure. Number of options remaining is the number count of options available to a decisionmaker. Input data are the number of decision points open (d_j), the number of options for each decision point (o_j), and the number of decisions (n). Output is:

$$\text{number of options} = (d_1)(o_1) + (d_2)(o_2) + \dots (d_n)(o_n) = \sum_{i=1}^n (d_i o_i)$$

2. Dimension of the measure. Interval -- the output is a positive potential number of options. It can be used in the form of proportion of options remaining.

3. Limits on the range of the measure. The output is a positive integer equal to or greater than twice the number of decision points. There is often some difficulty in determining the two input values and some tendency to estimate an infinite or very high number of options for a decision point.

4. Rationale for the measure. The measure is a direct indication of the amount of flexibility left to a commander. It is based on the theorem that more options is always more desirable albeit more confusing.

5. Relevance of the measure. The measure is intended to gauge the effectiveness of a C2 system. In the form proportion of options remaining the situation is compared to the number of options available before a decision was made.

6. Associated measures.

Amount of information conveyed

Time to decision

7. Application.

"Candidate MOE for Air Strike Systems," Naval Weapons Center Document #TP4687.

8. References.

MOE # 5: PERCENT ACTION INITIATED BY TIME ORDERED

1. Definition of the measure. Percent actions initiated by time ordered is the percentage of all actions initiated in response to orders that are initiated within the time specified by the order. (If the order does not specify a distinct time, it is counted as initiated on time regardless of delay). Input data are the times ordered and the times action is initiated. Relation of output to input is:

$$\text{percent actions initiated on time} = \frac{\text{number actions initiated by time ordered}}{\text{number actions ordered}} \times 100$$

2. Dimension of the measure. Ratio -- output is in the form of a percentage.

3. Limits on the range of the measure. The output can assume any value from 0 to 100 percent. The usefulness of the measure increases as the number of orders in the denominator with specified times increases.

4. Rationale for the measure. This measure addresses the timeliness of reaction to orders.

5. Relevance of the measure. The measure may be an indication of the effectiveness of C2 in the sense that when other factors are equal better C2 leads to faster reaction. This may make the measure useful in comparing alternative systems of C2. Alternatively, C2 may be held constant and this measure may distinguish between reaction systems.

6. Associated measures.

Time to first fire
Changes per order
Repetitions per order

Planning time
Mean length of orders
Percent moves completed on time

7. Application.

ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75, 15 August 1976.

8. References.

MOE # 6: MEAN DISSEMINATION TIME

1. Definition of the measure. Mean dissemination time is the time required to disseminate an order, directive, or warning to all elements at the next lower echelon of command. Input data are each time the order is approved and each time the last immediate subordinate headquarters acknowledges receipt. Relation of output to input is:

$$\text{mean dissemination time} = \sum \frac{[(\text{each time acknowledged}) - (\text{each time approval})]}{\text{number of orders}}$$

2. Dimension of the measure. Ratio -- output is an arithmetic mean in terms of average number of minutes and seconds.

3. Limits on the range of the measure. The measure may assume any positive value. The value is usually in terms of minutes since the only time involved is the time required to deliver or transmit a single message. A convention must be established for the possibility that an element fails to receive an order.

4. Rationale for the measure. The measure addresses on aspect of C2 directly, timeliness of disseminating orders. This is one area of C2 that can be expected to improve with technology.

5. Relevance of the measure. The usual application of the measure is evaluation of proposed technology to assist C2. The time measure does not stand alone but has to be used in conjunction with a measure of accuracy.

6. Associated measures.

Repetitions per order
Span of command

Changes per order

7. Application.

ACN 16849, MASSTER II Test.
ACN 17036, MASSTER III Test.
ACN 10784, Troop Test REDEYE.

8. References.

MOE # 7: PROPORTION FRIENDLY ELEMENTS ENGAGED

1. Definition of the measure. Proportion friendly elements engaged (also known as level of fratricide) is the quotient of the number of friendly elements erroneously engaged by fire to the number of all such friendly elements. Input data are the number of erroneous firing incidents and the total number of friendly elements. Relation of output to input is:

$$\text{Proportion friendly elements engaged} = \frac{\text{number friendly elements erroneously engaged}}{\text{number of friendly elements}}$$

2. Dimension of the measure. Ratio -- output is a proportion in decimal form.

3. Limits of the range of the measure. A proportion can vary from zero to one. The measure is made more complex if it includes different types of friendly elements.

4. Rationale for the measure. This measure addresses one of the most catastrophic failures in C3, the erroneous firing on friendly elements. In the referenced study it was applied to mistaken engagements of friendly aircraft by friendly air defense weapons.

5. Relevance of the measure. The measure is useful in assessing the accuracy of C3 in the situation where erroneous fire on friendly elements is possible in the event of failure.

6. Associated measures.

Required number of commands
Changes per order
Percent orders clarification requested

Mean dissemination time
Percent transmissions completed

7. APPLICATION.

ACN 10784, Troop Test REDEYE, 1967.

8. References.

MOE # 8: PERCENT ORDERS CLARIFICATION REQUESTED

1. Definitions of the measure. Percent orders clarification requested is the percentage of total orders issued including FRAGOs, for which any subordinate element requested clarification. Input data are the number of orders issued and the number of those orders for which one or more subordinate elements requested clarification in whole or part. Relation of output to input is:

$$\begin{array}{l} \text{percent orders} \\ \text{clarification} \\ \text{requested} \end{array} = \frac{\text{number orders clarification requested}}{\text{number of orders issued}} \times 100$$

2. Dimension of the measure. Ratio -- output is a percentage, in terms of percentage of orders.

3. Limits on the range of the measure. The output can assume any value from zero to one hundred percent. The measure is not very refined in that it ignores the effect of more than one request per order, ignores the possibilities of most requests coming from the same subordinate; and makes no distinction between minor points and crucial ambiguities. A more refined measure could be constructed to take these into account.

4. Rationale for the measure. The measure addresses quality of the C2 system indirectly by assessing the clarity of orders. It is assumed that a more effective C2 system has fewer requests for clarification.

5. Relevance of the measure. The measure is used to evaluate effectiveness of a C3 system when the system is defined as including both commander and subordinates. The measure cannot be used alone because greater delay could increase clarity. This measure is used in conjunction with a timeliness measure.

6. Associated measures.

Time to decision	Changes per order
Planning time forwarded	Repetitions per order
Span of control	Reaction time

7. Applications.

Reserve Components Revised ATT, USCONARC, March 1972

8. References.

MOE # 9: PERCENT PLANNING TIME FORWARDED

1. Definition of the measure. Percent planning time forwarded is the percentage of total planning time available that an echelon allows to all lower echelons. Input data are the total time from receipt of a mission (t_r) to time ordered to start execution (t_e), and time from receipt of mission (t_r) to issuance of the related order (t_o) to the next lower echelon. Relation of output to input is:

$$\text{percent planning time forwarded} = \left(1 - \frac{t_o - t_r}{t_e - t_r}\right) \times 100$$

$$\text{or } (1 - \text{time to decision ratio}) \times 100$$

2. Dimension of the measure. Ratio -- output is a percentage of total preparation time allowed. Several observations could be combined to mean percent planning time forwarded.

3. Limits on the range of the measure. Output can vary from 0 to 100 percent. It would be close to zero only when the order is given immediately to execute a contingency plan, or when an SOP is implemented. It would be 100 percent only if the echelon issuing the order used all the preparation time, not issuing the order until the intended time of execution had come.

4. Rationale for the measure. The measure addresses effectiveness of c2 by assessing how quickly planning is completed on an order issued in relation to the time available. Infantry School instruction includes the policy that each echelon should allow the next lower echelon 50% of the time it had available so that if a division receives a mission to attack in 24 hours, it should have its attack order to the brigades within 12 hours, the brigades should issue orders to the battalions within 6 hours and so forth. This measure is superior to elapsed planning time which is only a measure of performance. This MOE is truly a measure of effectiveness because the best possible performance (0 percent) is included in the measure.

5. Relevance of the measure. This MOE is intended to assess the effectiveness of a C2 system. It takes into account planning time, decision time, and time to prepare and disseminate orders.

6. Associated measures.

Elapsed planning time
Time to decision

7. Applications.

Reserve Components Revised ATT, USCONARC, March 1972

8. References.

MOE # 10: TIME FROM MISSION TO ORDER

1. Definition of the measure. Time from mission to order is the elapsed time at one echelon of command from the moment of receiving a mission from the next higher echelon(t_r) to the moment of issuing the responsive order to the next lower echelon (t_o). Input data are the two chronological times. Relation of output to input is the subtracted difference:

$$\text{time from mission to order} = t_o - t_r$$

2. Dimension of the measure. Interval -- an elapsed time in minutes, hours, or days as appropriate. Several observations could be combined into a ratio measure such as the mean time or expected time.

3. Limits on the range of the measure. The output may assume any positive measure. Since the main factors are nature of the mission and the echelon involved, the output value can not be separated from the conditions and these should probably be stated with the value, as for example, time from receipt of attack mission to battalion order.

4. Rationale for the measure. The measure directly addresses the timeliness of the command function. It includes planning time, decision time, and time to prepare and disseminate the order. It subsumes most of the important factors of difficulty in the command function, but does not include the factor of quality or soundness of the order.

5. Relevance of the measure. The measure can be used to compare alternative C2 systems on the timeliness aspect of effectiveness. Since the soundness of the order is not included, this measure would not be expected to stand alone, but would be used in conjunction with other measures.

6. Associated measures.

Planning time
Decision time

Time to prepare order
Dissemination time

(Any measure of soundness of orders)

7. Applications.

ACN 3067, Infantry Rifle Unit Study (IRUS) 1970-75, July 1976.

8. References.

MOE # 11: TIME TO DECISION RATIO

1. Definition of the measure. Time to decision ratio is the proportion of time from receipt of mission to time of execution action that is devoted to the commander's decision (this measure also called percent planning time used). Input data are the time of receiving the mission (t_r), time order is approved (t_o) which is counted as the final decision, and time execution of the ordered action is to start (t_e). Relation of output to input is:

$$\text{time to decision ratio} = \frac{t_o - t_r}{t_e - t_r}$$

2. Dimension of the measure. Ratio -- output is a pure number expressing the proportion of total time available devoted to reaching a decision.

3. Limits on the range of the measure. The output may vary from zero to unity. It could only be zero if the order is given without planning or consideration, and could only be unity if the order were not complete by the time the ordered action was to start.

4. Rationale for the measure. This measure addresses one aspect of the C2 system, the amount of time consumed in planning and preparing the order. It is assumed that a more effective C2 system (including commander, staff, standing operating procedures, and assisting technology) requires less of the available time for finalizing the order.

5. Relevance of the measure. The measure is used to evaluate a C2 system.

6. Associated measures.

Number orders required
Changes per order

Planning time forwarded

7. Applications.

None - this is a potential measure.

8. References.

MOE # 12: RATIO WARNING ORDERS TO OPERATIONS ORDERS

1. Definition of the measure. Ratio of warning orders to operations orders is the number of warning orders divided by the number of operations orders. Input data are the number of operations orders (including FRAGOS) and number of warning orders. Relation of output to input is the quotient:

$$\text{ratio of warning orders to operations orders} = \frac{\text{number of warning orders}}{\text{number of operations orders}}$$

2. Dimension of the measure. Ratio -- the output is a pure number expressing a ratio.

3. Limits on the range of the measure. The output value may vary from zero to unity.

4. Rationale for the measure. The measure addresses an aspect of effectiveness of C2, the issuance of warning orders prior to operations orders to assist reaction time. It is assumed that the higher the ratio is, the more effective in C2.

5. Relevance of the measure. The measure is used to evaluate a C2 system. It is a secondary measure in the sense that it indirectly addresses something that can be measured directly, reaction time. It has been used to measure level of training.

6. Associated measures.

Number of orders issued
time to decision

Planning time forwarded
Reaction time

7. Applications.

Reserve Components Revised ATT, USCONARC, Mar 72.

8. References.

MOE # 13: CHANGES PER ORDER

1. Definition of the measure. Changes per order is the arithmetic mean of the number of changes for each order issued. Input data are the number of orders issued and the number of changes made before execution of the order is completed. Relation of output to input is:

$$\text{changes per order} = \frac{\sum (\text{number of changes issued each order})}{\text{number of orders issued}}$$

2. Dimension of the measure. Ratio -- and average in terms of changes per order.

3. Limits of the range of the measure. The output value may be zero or any positive number. The usefulness of the measure increases as the size of the denominator increases.

4. Rationale for the measure. This measure addresses effectiveness of C2 indirectly. While some corrections to orders are ordinarily to be expected from a normally changing situation, an unusually high average from a normally changing situation, an unusually high average number of changes indicates difficulties in C2.

5. Relevance of the measure. The measure may be used to compare C2 systems on one aspect of effectiveness when other conditions are equivalent.

6. Associated measures.

Repetitions per order
Rate of orders

Planning time
Mean length of orders

7. Applications.

ACN 3067 - Infantry Unit Study (IRUS) 1970 -75, 15 Aug 76

8. References.

MOE # 14: REPETITIONS PER ORDER

1. Definition of measure. Repetitions per order is the arithmetic mean of the number of repetitions for each order issued. Input data are the number of orders issued and the number of repetitions of the same order (or part of an order) issued before the execution of the order is completed. Relation of output to input is:

$$\text{repetitions per order} = \frac{\sum (\text{number of repetitions issued each order})}{\text{number of orders issued}}$$

2. Dimension of the measure. Ratio -- An average in terms of repetitions per order.

3. Limits on the range of the measure. The output value may be zero or any positive number. The usefulness of the measure increases as the size of the denominator increases.

4. Rationale for the measure. The measure addresses effectiveness of command and control indirectly. While some repetitions of orders (or parts of orders) are ordinarily to be expected, an unusually high average of changes indicates difficulties in command and control.

5. Relevance of the measure. The measure may be used to compare command and control systems on one aspect of effectiveness when other conditions are equivalent.

6. Associated measures.

Change per order
Rate of orders

Planning time
Mean length of orders

7. Applications.

ANC 3067, Infantry Rifle Unit Study (IRUS) 1970-75, 15 August 1976.

8. References.

MOE # 15: REQUIRED NUMBER OF COMMANDS

1. Definition of the measure. Required number of commands is the simple number count of commands necessary to accomplish a stated mission. Input is the total count of commands.

2. Dimension of the measure. Interval -- A simple number count of commands. The measure could be taken in the form of a ratio, such as the average number of commands per mission, per objective, or per hour.

3. Limits of the range of the measure. There is no apparent limit of the output value; it can assume the value of zero or any positive integer. There is a serious limitation on the application of the measured output. It can only be applied in circumstances very similar to the circumstances under which it was observed.

4. Rationale for the measure. This measure can address difficulty in C2 in the sense that more commands may be required when C2 is more difficult. Alternatively if the difficulty of command and control is not variable, this measure may be an indication of facility in issuing commands.

5. Relevance Of The Measure. The measure may be used to compare C2 systems in effectiveness when conditions causing commands are relatively stable. In the referenced study it was used to determine whether new devices complicated C2 by requiring more commands.

6. Associated measures.

Changes per order
Reaction time (time to order)

7. Applications.

ACN 12944, Exploratory Examination in Night Operations Field Experiment 71.4
Jun 1968.

8. References.

MOE #16. NUMBER OF ORDERS ISSUED

1. Definition of the measure. Number of orders issued is the simple number count of the orders issued for a given operation. Input data is the number of orders.

2. Dimension of the measure.

Interval -- number of orders

3. Limits on the range of the measure. The output may assume any positive value. The value of the output is a function of several factors and can not be dissociated from the conditions under which the measure was taken.

4. Rationale for the measure. This measure directly addresses the amount of C2 and is considered an indication of the amount needed which relates to the cost of burden of C2.

5. Relevance of the measure. The measure may be used to compare alternative command and control systems under the same conditions.

6. Associated measures.

Changes per order
Repetitions per order

Planning time
Percent actions initiated in time

7. Applications.

ACN 3067 - Infantry Rifle Unit Study (IRUS) 1970-75, 15 August 76.

8. REFERENCES. None.